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Performance of purebred Welsh Mountain and crossbred ewes in a hill environment

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Abstract

The aim of this study was to compare the body weights, body condition scores, survival and litter weights of lamb produced by pure Welsh Mountain ewes with those of crossbred Cheviot, Lleyn, Poll Dorset and Texel ewes in a hill environment. Ewes were mated to Suffolk rams and recorded over the first 3 seasons of production. Between lambing and weaning, ewes rearing single lambs grazed semi-natural hill swards (1.5 ewes/ha) and those rearing twins grazed improved enclosures (10 ewes/ha). Crossbreeding significantly ($P<0.001$) increased body weights at all ages, with values for four-year old ewes of 45.9, 57.2, 51.6, 57.8 and 58.5 kg in purebred Welsh Mountain and Cheviot, Lleyn, Poll Dorset and Texel crossbred ewes respectively. Individual lamb growth rates from birth to 8 weeks and from 8 weeks to weaning were significantly higher in the progeny of crossbred ewes ($P<0.001$) with highest growth rates for lambs reared by Poll Dorset and Texel cross ewes. Individual lamb weaning weights were 27.0, 29.4, 29.2, 30.4 and 30.7 kg for lambs reared by purebred Welsh Mountain and Cheviot, Lleyn, Poll Dorset and Texel crossbred ewes respectively. Survival rates to third mating were 0.77, 0.72, 0.83, 0.75 and 0.73 ($P<0.05$), litter size reared was 1.22, 1.33, 1.49, 1.43 and 1.25 ($P<0.001$) and litter weights at weaning were 37.1, 43.5, 46.1, 46.5 and 44.2 ($P<0.001$) for purebred Welsh Mountain and Cheviot, Lleyn, Poll Dorset and Texel crossbred ewes respectively. Efficiency expressed as kg litter weight / kg ewe pre-tupping weight^{0.75} was significantly improved ($P<0.001$) by crossbreeding. Total litter weight at weaning over three lamb crops per ewe entering the flock was increased from 78.4 kg in purebred Welsh Mountain ewes to between 97.1 kg in Cheviot and 109.7 kg in Lleyn

crossbred ewes. It is concluded that where feed resources are adequate, the retention of crossbred ewes in the hill flock can give significant improvements in productivity.

Keywords: crossbreeding, hill sheep, litter size, lamb growth, weaning weight

Introduction

Approximately 40% of ewes in the United Kingdom are maintained in the hills and uplands (Pollott and Stone, 2006) and are adapted for survival on extensive grazing of unimproved, semi-natural pastures, in difficult climatic conditions. Typically, the ewes are purebred, are of low mature body size and produce slaughter lambs with light weight carcasses and poor conformation scores (Kempster and Cuthbertson, 1977). Within the stratified breeding system of the UK, hill breeds make a large genetic contribution to lamb meat production (Pollott and Stone, 2006), in part, through the direct slaughter of lambs produced by purebred hill ewes and, in part, through the contribution hill sheep make to the crossbred ewe populations maintained in the lowlands. Consequently, attempts to improve the genetic merit of hill ewes for maternal and meat characteristics are likely to have industry wide impact on the amount and quality of lamb meat produced. However, although within breed genetic improvement has been demonstrated to be effective in increasing mature size, maternal productivity and lamb growth and carcass quality (Ap Dewi et al., 2002; Conington et al., 2006; Lambe et al., 2005; Lambe et al., 2008), progress is restricted by the low number of recorded progeny involved in breed improvement schemes (Amer et al., 2007).

Crossbreeding offers the potential for more rapid change in ewe and lamb productivity than can be achieved by within breed selection and may bring enhanced performance due to heterosis. However, crossbreeding is little used in the hill environment (Rodriguez-Ledesma et al., 2011) due to the difficulties of managing the breeding programme on

unfenced pastures. Nevertheless, the effects of heterosis on ewe fertility, the survival and weaning weights of lambs (Nitter, 1978) justifies attempts to manage crossbreeding in these harsh environments. The relative benefits of complementarity and heterosis have been demonstrated for crosses of a range of hill breeds with local Scottish Blackface stock (Al-Nakib et al., 1997). Evaluations of more extreme crosses (including Lleyn and Texel) demonstrated enhanced individual and lifetime performance relative to the purebred Scottish Blackface (Annett et al., 2011a; Annett et al., 2011b) without apparent detrimental effects on ewe mortality or lamb survival. The knowledge gained from such crossbreeding studies may be applied directly to improve productivity in regular crossbreeding systems, or indirectly in the creation of composite breeds which may bring benefits in terms of ease of management, a planned mix of complementary traits, retained heterosis and flexibility in future breeding plans.

The Welsh Mountain is numerically the second largest UK breed and represents approximately 10% of the UK ewe flock (Pollott and Stone, 2006). The mature size of the Welsh Mountain ewe is the lowest of the commercial breeds in the UK although this varies widely with strain differences (Friggens et al., 1997) that reflect local variations in pasture quality. Changes in subsidy payments from headage-based to area-based schemes, has encouraged a reduction in stocking rates and raised the potential for the introduction of larger, more productive ewes based on within breed selection, breed substitution or crossbreeding (Rodriguez-Ledesma et al, 2011), which may reduce dependence on subsidy payments (Ripoll-Bosch et al, 2013). The aims of this work were to compare the performance and survival of purebred Welsh Mountain ewes and Cheviot,

Poll Dorset and Texel crossbred Welsh Mountain ewes in a hill environment. Cheviot rams were chosen to increase body size whilst retaining hardiness, the Lleyn for maternal characteristics, the Dorset for its longer breeding season and earliness of maturity, and the Texel for its carcass qualities and current, commercial use as a component of crossbred ewes in the upland environment.

Materials and methods

This work was conducted at Pwllpeiran farm in the Cambrian mountains of West Wales, UK. The farm extends to 1346 ha of grazing land between 200 and 625 m above sea level. Annual rainfall ranges between 1700 mm and 2200 mm depending upon elevation. Approximately 29% of the farm area is improved perennial ryegrass (*Lolium perenne*) based swards which are used for silage conservation, grazing of twin rearing ewes and lamb finishing. The remainder of the farm provides semi-natural rough grazing, consisting of mosaics of sown fine leaved grasses and degraded areas dominated by *Nardus stricta*, *Juncus effusus*, *Vaccinium myrtillus* and *Calluna vulgaris*.

The work was carried out in two phases with the production of crossbred ewes from Welsh Mountain dams in the first (McLean et al., 2006), and the evaluation of crossbred ewe performance in the second. Over three years (2000-2002) Cheviot, Poll Dorset, Lleyn and Texel rams were selected from the top 20 % available from breed-wide sire reference schemes and mated to 600 Welsh Mountain ewes per year using laparoscopic AI. Overall, eight rams were used per breed: two in year one and three/year

subsequently. Single born crossbred lambs were reared on semi-natural rough hill grazing and twins on improved pastures until weaning at 16 weeks of age. At weaning, 50 ewe lambs per crossbred type per year were retained for breeding. Pure Welsh Mountain ewe lambs were selected from the parent Welsh Mountain flock at weaning and run with the crossbred ewe lambs as a single group on improved swards of perennial ryegrass dominant pastures until October. In October all ewe lambs were sent to lowland swards of perennial ryegrass for wintering until late March. Subsequently, they grazed hill pastures until 3 weeks before mating, when they were moved to improved pastures for flushing.

During 2002-2006, all ewes in the crossbred evaluation phase of the trial were allocated to mating groups at random within crossbred ewe type and age group. Ewes were mated by natural service using Suffolk rams at a ratio of 50 ewes per ram (10 ewes per crossbred ewe type) over an approximately twenty eight day breeding period. Ewes that did not conceive during this period were covered by Texel sweeper rams and excluded from the data base for that season of production. Ultrasonic pregnancy diagnosis was undertaken in January each year. All ewes in their first parity (two years old) were housed for the final 6 weeks of pregnancy and fed grass silage and concentrates according to predicted litter size. In subsequent parities only twin and triplet bearing ewes were housed. Single bearing ewes were maintained on pastures and fed grass silage supplemented with feed blocks until lambing. After lambing, single bearing ewes were grazed on semi-natural hill pastures at 1.5 ewes per ha, whilst twin rearing ewes were

retained on improved perennial ryegrass (*Lolium perenne*) based swards at up to 10 ewes per ha until lambs were weaned at 18 weeks of age.

Pre-mating and post-weaning live weights and body condition scores (measured to the nearest 0.25 units on a scale of thin (1) to fat (5)) were recorded for the ewes (Russel et al., 1969). All lambs were weighed at birth, eight weeks and weaning at eighteen weeks of age. Data analyses were restricted to lambs born within the first three litters for each ewe and reared in the years 2003-2007.

Statistical methods

The database was edited to exclude records with missing information about fixed effects (litter size, sex of lamb, age of ewe) and, in the derivation of litter weight traits, female lamb weights and average daily gains (ADG) were adjusted by adding a value for the mean difference between males and females derived from analyses of individual lamb performance.

Analyses were conducted to fit general linear models using the REML algorithm of GenStat (Lawes Agricultural Trust, 2007). For lamb growth traits, main effects were tested for breed of sire of dam (Cheviot, Poll Dorset, Lleyn, Texel and Welsh Mountain), year (five levels), age of ewe (two, three and four), litter size born or reared (single, twin, triplet) and sex (male catrate and female). Linear covariates were fitted for either day of birth or the relevant age at measurement. All two and three way interactions were tested

following a stepwise procedure and non-significant ($P>0.05$) interactions and main effects were excluded from the final models (Tables 1). Models for the analysis of ewe litter traits were derived following a similar procedure, testing main effects for breed of sire of ewe, year, age of ewe (Table 2). Ewe survival was evaluated as presence or absence at the third mating and analysed as a binomial trait using a logarithmic link function in a generalized linear model. Information about the sires of the ewes and their lambs was incomplete and could not be fitted in these analyses. Consequently, ewe identity (dam identity for lamb traits) was fitted as a random effect. Where the effects of breed were found to be significant ($P<0.05$) differences between breed means were evaluated using least significant difference tests.

TABLES 1 AND 2 ABOUT HERE

Results

TABLE 3 ABOUT HERE

Means and standard deviations (Table 3) indicate coefficients of variation of 19-24% for weight for age and ADGs, with a high level of variation shown in ADG from eight weeks to weaning, a period when average growth rates were low. Litter weights and growth rates were more variable (coefficients of variation around 32-39%) which would be expected for traits that combine individual lamb performance with litter size.

Performance of Suffolk sired lambs from crossbred ewes

The mean performance of lambs from crossbred ewes was greater than those from pure-bred Welsh Mountain ewes at all stages from birth to weaning (Table 4). Breed x year

TABLE 4 ABOUT HERE

interactions, which were significant for weights at birth and for ADG from birth to 8 weeks and weaning, were generally interactions in the scale of differences among crossbred ewe types and were too small to be of practical importance. Although lambs born to Texel cross ewes were heavier at birth, they did not differ significantly from lambs reared by Poll Dorset cross ewes in weight or growth rate at later ages. At weaning, lambs from the Poll Dorset and Texel crossbred ewes were 12.7 and 14.2% heavier respectively than the pure Welsh Mountain lambs. Lambs bred by Lleyn and Cheviot cross ewes did not differ in performance ($P>0.05$), with weaning weights that were respectively 8.2 and 9.0% higher than for Welsh Mountain lambs. Growth rates between eight weeks and weaning, a period of ten weeks, were low and did not differ significantly among the crossbred ewe types ($P>0.05$), although higher growth rates were observed for lambs reared by crossbred mothers compared to those reared by Welsh Mountain ewes ($P<0.05$).

TABLE 5 ABOUT HERE

Performance of crossbred ewes

Litter size born and reared to weaning (Table 5) did not differ significantly between Texel crossbred ewes and the Welsh Mountain ($P>0.05$), but litter size at birth was increased in other crossbred types by between 0.13 lambs per ewe lambing in the Cheviot cross to 0.25 lambs per ewe lambing in the Lleyn cross. Approximately 0.2 lambs per ewe were lost in all breeds over the rearing period and crossbred ewe types were ranked similarly for litter size at birth and weaning.

Litter weights at birth did not differ among crossbred ewe types ($P>0.05$) but all were significantly ($P<0.001$) higher than the Welsh Mountain. Litter weights weaned were between 17% (Cheviot x) and 25% (Poll Dorset x) higher in crossbred ewes than in the Welsh Mountain ($P<0.001$). Similarly, litter weight per ewe lambing expressed as a proportion of ewe metabolic weight (pre-tupping weight^{0.75}) was higher in crossbred ewes than in the Welsh Mountain ($P<0.001$), with a high value for Lleyn crosses. Litter growth rates from birth to weaning were improved by crossbreeding ($P<0.001$) and were higher in the Poll Dorset x than in the Cheviot x ($P<0.05$), with intermediate values for the Lleyn and Texel crossbred ewes. However, although crossbred ewes outperformed the purebred Welsh Mountain at all stages of lactation, only small differences were observed among crossbred ewe types for litter ADG from birth to eight weeks, with no significant differences among crossbred ewe types for litter ADG from eight weeks to weaning ($P>0.05$).

TABLE 6 ABOUT HERE

The effect of breed type on the proportion of ewes that survived to the third mating (Table 6) was not significant ($P>0.05$). The total litter weight weaned per ewe over three lamb crops was increased relative to the purebred Welsh Mountain by 40%, 32%, 28% and 24% for the Lleyn, Poll Dorset, Texel and Cheviot crossbred ewes respectively ($P<0.001$).

TABLE 7 ABOUT HERE

By weaning in the third production cycle, the mean live weight of four-year old Welsh Mountain ewes was 45.9 kg (Table 7). The mean live weights of crossbred ewes were between 11.3 to 12.6 kg higher than the Welsh Mountain for the Cheviot, Poll Dorset and Texel crosses, and 5.7 kg higher for the Lleyn cross. Body condition scores were marginally lower ($P<0.001$) in the Lleyn cross than for other breed types at first mating, and in the Welsh Mountain at the third mating. The difference (loss) in body condition between mating and weaning in the first production cycle was not significantly different ($P>0.05$) among breed types, but was greatest in Cheviot and Lleyn crosses in the third cycle of production ($P<0.05$). Consequently, with the exception of the Lleyn cross, crossbred ewes maintained satisfactory body condition scores through to weaning when compared to the purebred Welsh Mountain.

Discussion

The adult weights of commercial Welsh Mountain ewes are variable, depending on genetic strain and environmental conditions, and this may influence the applicability of the results of the current study where ewe and lamb performance has been improved in part, through an increase in the potential mature size of the crossbred ewe. Published estimates of the mature size of Welsh Mountain ewes range from 36 kg (Hughes et al., 1985; Thonney et al., 1987), 42 kg (Al-Nakib and King, 1989; Gunn et al., 1991), and 46 to 50 kg (Wiener, 1967; Wiener, 1973; Wiener and Hayter, 1974). Estimates of mature size vary with both short- (Gunn et al., 1991) and long-term nutrition (Wiener and Hayter, 1974). Wiener (1973) found that the same genetic stock of Welsh Mountain ewes had a mature weight of 34 kg on the hill, but grew to 47 kg under good conditions of upland grazing. On non-limiting diets the mature weights of Welsh Mountain ewes were 61 kg (Friggens et al., 1997). Given the conclusion of Thonney et al. (1987) that the mature weights of hill breed ewes reared on experimental diets, which allowed a full expression of fatness, were approximately 1.3 times higher than those for ewes reared under commercial conditions, Friggens et al. (1997) estimated a mature size for commercial ewes of 47 kg, which is close to the value of 45.9 kg reported in this study for four-year old ewes from genetically improved lines.

Crossbreeding increased the live weight of four-year old ewes by a factor of 1.12 for the Lleyen cross and by 1.25, 1.26 and 1.27 for the Cheviot, Poll Dorset and Texel crosses respectively. These increases in adult body weight are proportionally greater than those

reported by Annett et al., (2011b), which is to be expected from the smaller mature size of the Welsh Mountain (45.9 kg in this study) relative to the Scottish Blackface (52.8 kg in the report of Annett et al., 2011b). The ranking of Cheviot and Lleyn crossbred ewes for adult body weight was similar to that reported by Annett et al., (2011b), though Texel crossbreds were larger in the current study, perhaps due to differences in the genetic lines used. It is likely that the mature weights attained by the crossbred ewes have been restricted, since predictions of the mature size of the crossing sire breeds (based on the differences between crossbred and purebred adult weights) are below expectations from estimates drawn from pedigree flocks on higher planes of nutrition (Cameron and Drury, 1985). Despite this potential restriction, and recognizing that poor body condition may have been a direct or indirect reason for early culling of ewes, target body condition scores of the larger crossbreds were maintained over three lamb crops, indicating that they were able to sustain higher levels of productivity than the Welsh Mountain without excessive loss of body condition. Thus crossbreeding provides a rapid means of increasing the body size of the ewe, which will have implications both for increased individual lamb growth and carcass production and for reduced stocking rates.

The litter size born per Welsh Mountain ewe lambing of 1.40 was within the range of published values of 1.57 (Al-Nakib and King, 1989), 1.46 (Wiener, 1967) and 1.15-1.40 with variation due to pre-mating nutrition (Gunn et al., 1991). Crossbreeding increased litter size born and reared, in a manner that was consistent with the results of Annett et al., (2011b) for all except the Texel crossbreds, which showed no significant improvement over the Welsh Mountain ($P>0.05$). The reduction in litter sizes between

birth and weaning suggests an overall lamb mortality rate which is in agreement with the value of 0.125 reported by Annett et al., (2011b), and indicates that under the husbandry conditions of this flock, there was no excess of lamb mortality due to the initially higher litter sizes of the crossbred ewes.

Individual lamb growth rates were comparable with those of the first cross lambs from Welsh Mountain ewes in this experiment (McLean et al., 2006) or from Scottish Blackface ewes (Speijers et al., 2010) and marginally lower than the growth rates of pure and crossbred lambs from Blackface and Cheviot ewes reported by Carson et al. (2001). We are aware of no other reports of the growth rates of pure Welsh Mountain lambs under commercial conditions, although ADGs of 177 g/day between 0.40 and 0.52 of maturity (Thonney et al., 1987) and of 187 g/day from 8 to 24 weeks (Friggens et al., 1997) have been recorded for weaned female lambs on high quality experimental diets. The growth advantage of lambs from Poll Dorset and Texel compared to Cheviot and Lleyn crossbred ewes was exhibited only in early lactation and was not observed after 8 weeks of age, suggesting that nutrition during weaning was not adequate to meet the genetic potential of these animals for growth. A similar lack of discrimination between genetic types in the weaning period has also been observed in the hill environment for first cross lambs reared by Welsh Mountain ewes (McLean et al., 2006) or Scottish Blackface ewes (Speijers et al., 2010) and for differences between Blackface and Cheviot ewes (Carson et al., 2001).

Litter weight weaned per ewe lambing in a single year was substantially increased by 1.17 (Cheviot cross) to 1.25 (Poll Dorset cross). Cheviot and Texel crossbred ewes were shown to have similar levels of performance (Annett et al., 2011b) and litter weights at weaning were similar for the Dorset and Texel when used as sire breeds mated to common dam types (Freking et al., 1995). Lamb growth rates and weaning weights are expected to be proportional to mature size (Cameron and Drury, 1985) and it is likely that larger ewes will be maintained at lower stocking rates, perhaps with little or no improvement in output per hectare (Vipond et al., 1987). However, largely as a result of higher litter size (Schoeman et al., 1995), the output of weaned lamb per unit metabolic weight was also greater in crossbred ewes. This effect was marginally greater than that reported by Annett et al. (2011b) who noted smaller increases in litter size weaned in crossbred ewes relative to the Scottish Blackface than were observed relative to the Welsh Mountain in the current study. Under the conditions of this experiment, crossbred ewes were managed at equivalent stocking rates (ewes/ha) to the smaller purebred Welsh Mountain ewe and achieved greater lamb output and efficiency. These benefits may only be achievable where an adequate area of better quality grassland is available to realize the increased potential of crossbred animals for growth and litter size. The ability to maintain larger litter sizes may be restricted on many hill farms and there is also the possibility that, where twin rearing ewes are transferred to improved pastures, a lower number of single bearing ewes will be available for the grazing management of upland pastures. However, there are many areas of upland Wales where these issues are unlikely to be important and current Welsh Mountain sheep could be replaced by more productive crossbred ewes.

Lifetime performance, the product of ewe survival, reproductive performance and maternal ability, is the ultimate determinant of the acceptability of crossbred ewes. Survival rates to third mating as three and a half-year old ewes were similar to those reported for Scottish Blackface ewes and their crosses (Annett et al., 2011a). Similarly, Annett et al., 2011a did not observe significant differences in the survival of crossbred ewes relative to the pure Scottish Blackface. In comparison to the Welsh Mountain, the litter weight weaned over three lambing opportunities per ewe entering the flock was increased by 25% (Cheviot cross) to 40% (Lleyn cross), with levels of productivity for four-year old crossbred ewes that were comparable to the results of Annett et al. (2011a). The pathway to this improvement differed between the crossbreds, such that the Lleyn cross produced the highest total performance via a larger litter size reared with lower individual lamb performance; whereas Poll Dorset and Texel crosses benefitted from improved individual lamb performance and, in the case of the Poll Dorset, a higher litter size. The improvement in total performance achieved by the Cheviot cross ewe was largely due to improved individual performance of the lambs and a non-significant increase in litter size reared. It is noteworthy that absolute values for lifetime performance and differences among crossbred ewe types might change marginally where ewes are allowed a full commercial cycle of mating of up to forty two days. Similarly, it is possible that if ewes were retained for more than three lambing seasons, the ranks of the crossbred types for lifetime performance could change due to increased pressures on survival and performance in older ewes (Annett et al., 2011a).

This work has demonstrated that, where resources are adequate, the retention of crossbred Welsh Mountain ewes offers a method of rapid improvement in ewe productivity and efficiency on hill and upland farms that currently manage small, purebred Welsh Mountain ewes. Similar levels of overall performance were achieved in different crossbred ewe types through different combinations of litter size, and lamb growth, and the final choice of crossbred type for use will depend on the relative emphasis placed on these traits and on the slaughter age and weight, and carcass characteristics of their lambs. In the first phase of this experiment Poll Dorset and Texel cross Welsh Mountain lambs were shown to have significantly lower slaughter age and higher carcass weight than Cheviot and Lleyen crossbred lambs (McLean et al., 2006). Furthermore, the use of a terminal sire breed with crossbred ewes is expected to further enhance the slaughter characteristics of the lamb (Carson et al., 1999) and thus crossbreeding can facilitate both improved maternal performance and enhanced carcass quality, marketability and consumer satisfaction from hill bred lambs, with further benefits to the carcass qualities of crossbred ewes at lower levels of the stratified breeding system. However, the benefits of crossbreeding in the hills can only be achieved where there are adequate enclosures to enable the mating management of pure and crossbred ewe stocks and where feed resources are adequate to realise the potential for enhanced performance of crossbred ewes with a greater proportion of twin lambs. Further work may be required to investigate the pattern of weight gain or loss in hill bred lambs in the immediate pre- and post-weaning periods, with the aim of determining the optimum weaning date and best use of quality grazing. Alternatively, evidence such as that presented in this paper could be used in the development of new composite breeding stock.

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Ethical approval

Procedures were approved by the Pwllpeiran Ethics Committee as part of ADAS

Standard Operating Procedures.

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Table 1 Statistical models used for the analysis of the pre-weaning traits for Suffolk cross lambs bred from crossbred ewes

	Day of birth	Birth weight	Eight week weight	Weaning weight	ADG [†] B-8W	ADG [†] B-W	ADG [†] 8W-W
Breed (of sire of ewe)	***	***	***	***	***	***	*
Year	***	***	***	***	***	***	***
LSB [§]	**	***	***	***	***	***	***
LSR [§]				***		***	**
Ewe age		***	***	***	***	**	
Sex		***	***	***	***	***	***
Birth date		*			***		
Age covariate			***	***	***	***	***
Breed x year		***			**	***	
Year x age covariate			***	***	**	***	***
Year x birth date		***			**		

[†] Average daily gain (ADG) from birth to 8 weeks (B-8W), birth to weaning (B-W) and 8 weeks to weaning (8W-W)

[§] LSB and LSR are litter size born and litter size reared respectively

* P<(0.05), ** P<(0.01), *** P<(0.001)

Table 2 Statistical models used for the analysis of pre-weaning litter traits of ewes

	Litter size:		Litter weight at:			Litter ADG:		
	Born	Reared	Birth	8W [†]	Weaning	B-8W [†]	B-W	8W-W
Breed (of sire of ewe)	***	***	***	***	***	***	***	**
Year	***	***	***	***	***	***	***	***
Ewe age	***	***	***	***	***		***	
Birth date / Age covariate	***	***	**	***		***	***	***
Breed x year			**		*		**	*
Breed x Ewe age				*	*	**	*	
Year x age covariate				***		***		

[†] Litter weight at 8 weeks (8W); Litter average daily gain from birth to 8 weeks (B-8W), birth to weaning (B-W); and eight weeks to weaning (8W-W)

* P<(0.05), ** P<(0.01), *** P<(0.001)

Table 3 Uncorrected means and standard deviations for ewe performance traits and for the pre-weaning performance of their Suffolk cross lambs

Trait	Number	Mean	Standard deviation
Day of birth [†]	2266	97.8	8.62
Age at weaning (days)	1981	127.7	12.98
Birth weight (kg)	2251	3.8	0.94
Eight week weight (kg)	2034	20.5	4.94
Weaning weight (kg)	1981	29.2	5.49
ADG (kg/day):			
Birth – eight weeks	1833	0.25	0.052
Birth – weaning	1968	0.20	0.038
Eight weeks – weaning	1758	0.14	0.070
Litter size:			
Born	1500	1.52	0.542
Reared	1500	1.32	0.642
Litter weights (kg) at:			
Birth	1487	6.0	1.93
Eight weeks	1408	30.5	11.75
Weaning	1381	43.2	15.37
Litter ADG (kg/day):			
Birth – eight weeks	1260	0.38	0.148
Birth – weaning	1369	0.29	0.111
Eight weeks – weaning	1230	0.21	0.114

[†] Number of days from January 1st in each year

Table 4 Effect of breed of sire of dam on the pre-weaning performance of Suffolk cross lambs bred from pure Welsh Mountain or crossbred ewes

	Breed of sire of ewe					s.e.d. [†]	Significance
	Cheviot	Poll Dorset	Lleyn	Texel	Welsh Mountain		
Day of birth	98.4 ^b	97.5 ^b	98.2 ^b	97.8 ^b	101.0 ^a	0.67	***
Birth weight (kg)	3.7 ^{bc}	3.8 ^c	3.6 ^b	4.0 ^d	3.2 ^a	0.07	***
Eight week weight (kg)	20.1 ^b	20.9 ^c	20.1 ^b	21.4 ^c	18.4 ^a	0.30	***
Weaning weight (kg)	29.2 ^b	30.2 ^c	29.0 ^b	30.6 ^c	26.8 ^a	0.38	***
ADG (kg/day):							
Birth – weaning	0.20 ^b	0.21 ^c	0.20 ^b	0.21 ^c	0.19 ^a	0.003	***
Birth – eight weeks	0.25 ^b	0.26 ^c	0.24 ^b	0.26 ^c	0.23 ^a	0.004	***
Eight weeks – weaning	0.15 ^b	0.15 ^b	0.15 ^b	0.15 ^b	0.14 ^a	0.004	*

[†] s.e.d. standard error of difference

* P<(0.05), ** P<(0.01), *** P<(0.001)

^{a, b, c, d} Means within a row with different superscripts are significantly different (P<0.05)

Table 5 Effect of breed of sire of ewe on pre-weaning litter production per ewe lambing

	Breed of sire of ewe					s.e.d. [†]	Significance
	Cheviot	Poll Dorset	Lleyn	Texel	Welsh Mountain		
Litter size:							
Born	1.53 ^{bc}	1.62 ^{cd}	1.65 ^d	1.46 ^{ab}	1.40 ^a	0.048	***
Reared	1.33 ^{ab}	1.43 ^{bc}	1.49 ^c	1.25 ^a	1.22 ^a	0.058	***
Litter weights (kg) at:							
Birth	6.2 ^b	6.4 ^b	6.3 ^b	6.2 ^b	5.2 ^a	0.17	***
Eight weeks	32.6 ^b	35.2 ^c	32.7 ^b	33.1 ^b	28.1 ^a	0.98	***
Weaning	43.5 ^b	46.5 ^c	46.1 ^{bc}	44.2 ^{bc}	37.1 ^a	1.40	***
Efficiency [§]	2.47 ^b	2.56 ^{bc}	2.71 ^c	2.50 ^b	2.31 ^a	0.077	***
Litter ADG (kg/day):							
Birth – eight weeks	0.40 ^b	0.43 ^c	0.41 ^{bc}	0.41 ^{bc}	0.35 ^a	0.012	***
Birth – weaning	0.30 ^b	0.32 ^c	0.32 ^c	0.30 ^{bc}	0.25 ^a	0.010	***
Eight weeks – weaning	0.22 ^b	0.23 ^b	0.24 ^b	0.22 ^b	0.20 ^a	0.009	**

[†] s.e.d. standard error of difference

Table 6 Effect of breed of sire of ewe on litter weight production (kg) per ewe over three years

	Breed of sire of ewe					s.e.d. [†]	Significance
	Cheviot	Poll Dorset	Lleyn	Texel	Welsh Mountain		
Survival to third mating	0.77 [§]	0.72	0.83	0.75	0.73	0.069	
Litter weight produced at:							
Birth	13.7 ^b	14.2 ^{bc}	15.1 ^c	14.1 ^{bc}	11.1 ^a	0.61	***
Eight weeks	73.1 ^b	78.0 ^{bc}	80.6 ^c	74.9 ^{bc}	59.5 ^a	3.40	***
Weaning	97.1 ^b	103.3 ^{bc}	109.7 ^c	100.5 ^b	78.4 ^a	4.59	***

[†] s.e.d. standard error of difference

[§] Means are back-transformed from the scale of natural logarithms

* P<(0.05), ** P<(0.01), *** P<(0.001)

^{a, b, c} Means within a row with different superscripts are significantly different (P<0.05)

Table 7 Effect of breed of sire of ewe on ewe body weights and condition score at critical stages of production

	Breed of sire of ewe					s.e.d. [†]	Significance
	Cheviot	Poll Dorset	Lleyn	Texel	Welsh Mountain		
Weight (kg) at:							
First mating	42.1 ^c	43.0 ^{cd}	38.9 ^b	43.3 ^d	37.2 ^a	0.57	***
First weaning	46.9 ^c	47.6 ^c	42.9 ^b	48.1 ^c	38.9 ^a	0.74	***
Third mating	50.3 ^c	50.9 ^c	46.9 ^b	51.2 ^c	42.5 ^a	0.86	***
Third weaning	57.2 ^c	57.8 ^c	51.6 ^b	58.5 ^c	45.9 ^a	1.00	***
Body condition score at:							
First mating	3.09 ^b	3.13 ^b	2.91 ^a	3.15 ^b	3.04 ^b	0.059	***
First weaning	2.8 ^{bc}	2.9 ^{cd}	2.6 ^a	3.0 ^d	2.7 ^{ab}	0.069	***
Third mating	3.34 ^c	3.20 ^{bc}	3.17 ^{ab}	3.30 ^{bc}	3.04 ^a	0.079	**
Third weaning	2.88 ^b	2.91 ^{bc}	2.69 ^a	3.08 ^c	2.78 ^{ab}	0.089	***
Body condition score loss:							
First mating to weaning	0.30	0.28	0.29	0.16	0.29	0.092	n.s.
Third mating to weaning	0.55 ^c	0.35 ^{ab}	0.51 ^{bc}	0.33 ^{ab}	0.29 ^a	0.101	*

[†] s.e.d. standard error of difference

* $P < (0.05)$, ** $P < (0.01)$, *** $P < (0.001)$, n.s. not significant ($P > 0.05$)

^{a, b, c, d} Means within a row with different superscripts are significantly different ($P < 0.05$)